Agilent Technologies

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Fourier Theory & Practice, Part I: Theory (Agilent Product Note 54600-4)

Appendix B

By:
Robert Witte
Agilent Technologies

Introduction:

This product note provides a brief review of Fourier theory, especially the unique behavior of the FFT. The note also describes some typical applications and provides some tips on how to get the most out of the FFT capability of the Agilent 54600 series scopes with an Agilent 54657A or Agilent54658A FFT module.

Equipment Required

- Agilent 54622A or Agilent 54600B Oscilloscope with FFT option (Note: units operate differently in some cases.)

Fourier Theory

Normally, when a signal is measured with an oscilloscope, it is viewed in the time domain (Figure 1a). That is, the vertical axis is voltage and the horizontal axis is time. For many signals, this is the most logical and intuitive way to view them. But when the frequency content of the signal is of interest, it makes sense to view the signal in the frequency domain. In the frequency domain, the vertical axis is still voltage but the horizontal axis is frequency (Figure 1b). The frequency domain display shows how much of the signal's energy is present at each frequency. For a simple signal such as a sine wave, the frequency domain representation does not usually show us much additional information. However, with more complex signals, the frequency content is difficult to uncover in the time domain and the frequency domain gives a more useful view of the signal.

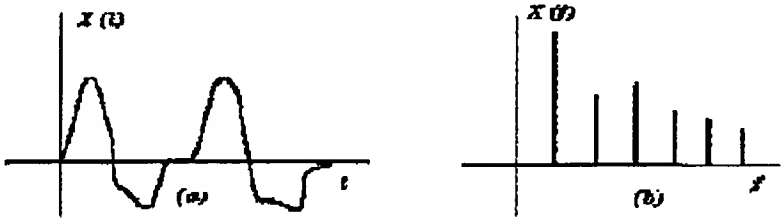

figure 1

(a) A signal shown as a function of time.
(b) A signal shown as a function of frequency.

Fourier theory (including both the Fourier Series and the Fourier Transform) mathematically relates the time domain and the frequency domain. The Fourier transform is given by:

$$V(f) = \int_{-\infty}^{\infty} v(t)\, e^{-j2\pi ft}\, dt$$

We won't go into the details of the mathematics here, since there are numerous books which cover the theory extensively (see references). Some typical signals represented in the time domain and the frequency domain are shown in Figure 2.

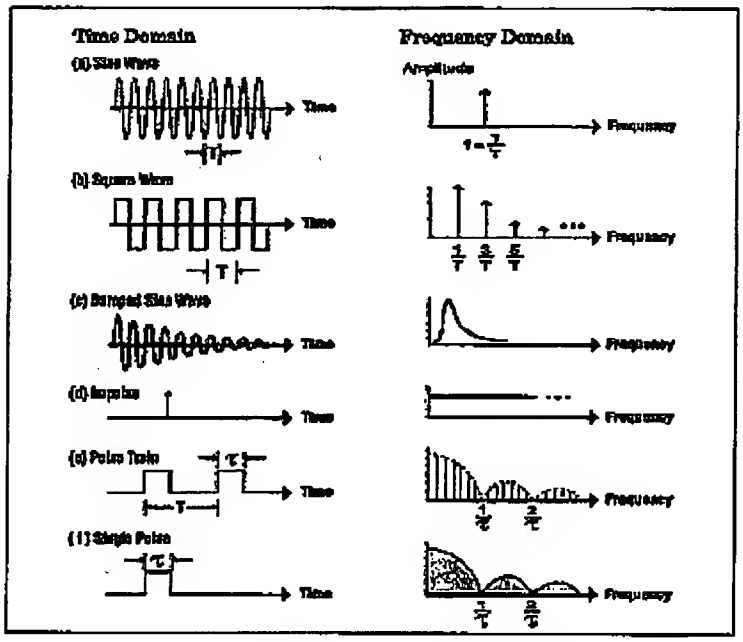

Figure 2: Frequency spectrum examples

The Fast Fourier Transform

The discrete (or digitized) version of the Fourier transform is called the Discrete Fourier Transform (DFT). This transform takes digitized time domain data and computes the frequency domain representation. While normal Fourier theory is useful for understanding how the time and frequency domain relate, the DFT allows us to compute the frequency domain representation of real-world time domain signals. This brings the power of Fourier theory out of the world of mathematical analysis and into the realm of practical measurements. The Agilent 54600 scope with Measurement/Storage Module uses a particular algorithm, called the Fast Fourier Transform (FFT), for computing the DFT. The FFT and DFT produce the same result and the feature is commonly referred to as simply the FFT.

The Agilent 54600 series scopes normally digitize the time domain waveform and store it as a 4000 point record. The FFT function uses 1000 of these points (every fourth point) to produce a 500 point frequency domain display. This